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ON THE

VENTILATION

OF

DWELLING-HOUSES & SCHOOLS,

ILLUSTRATED BY DIAGRAMS;

WITH REMARKS UPON

SANITARY IMPROVEMENTS:

BEING THE SUBSTANCE OF

TWO LECTURES DELIVERED BEFORE THE BOARD OF ARTS AND MANUFACTURES FOR LOWER CANADA;

BY

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PREFATORY NOTICE.

THE Committee of the Board of Arts and Manufactures for Lower Canada made arrangements for the delivery of a series of Lectures in the Mechanics' Hall, Montreal, during the winter of 1857–58; having selected, amongst other useful and interesting topics, the important subject of *Sanitary Science.* The following discourse was therefore prepared and delivered, at their request, with the assistance of such materials and illustrative local information as the author happened to have access to at the time. The chief purpose, however, of all the lectures was to present practically useful information, in as popular a form as possible, so that the subject of Ventilation is here treated of with only such reference to abstract scientific details as appeared to the author absolutely essential to an intelligent comprehension of its general nature and objects.

The discourse is now printed and published at the instance of several gentlemen, members of the press and others, who imagine that some good may thus result from an endeavor to excite increased attention to matters much neglected in the community, though of deep importance to its well-being.

VENTILATION

OF

DWELLING-HOUSES AND SCHOOLS.

CHAPTER I.

GENERAL OBSERVATIONS UPON THE NATURE AND OBJECTS OF SANITARY MEASURES.

AMONGST the applications of labour and ingenuity in the common concerns of life, none present stronger claims upon our attention than those which are specially devoted to the prevention and mitigation of human suffering. Such purposes as these, indeed, enter more or less directly as ends to be secured in most undertakings; for even men's various callings and professions may be said to be founded, in some measure, upon the necessity of coping with the evils of their earthly condition.

But I would desire here to be understood as referring to that extensive class of evils proceeding from purely physical causes—inseparable accompaniments of the growth of every community—which, it is believed, become *unnecessarily*, through neglect and want of adequate precaution, the occasion of a vast amount of the misery witnessed in the world.

Some progress has undoubtedly been made of late years towards resisting the operation of such causes by a more systematic introduction of what are termed "Sanitary Measures" in the cities and

populous districts of most civilized countries. Yet it is to be feared that we are far from having arrived at a perception of their real nature, objects, and value, so as thoroughly to realize their necessity, or to establish that hearty and general concern which can alone secure their efficient carrying out.

Considerations of a purely scientific nature would of themselves suggest the need of precautions for the defence of health. But, as regards people in general, the lessons of science—especially those of Chemistry and Physiology, so much concerned in our present subject—are inculcated in vain. Sad experience, then, both in the Old World and in the New, proves in the end to be the chief incentive to activity in the right direction. For those who have made sanitary improvements the subject of particular study—the medical profession, statistical writers, Sanitary Commissioners, Boards of Health, and scientific men in general—concur in bearing testimony to the indifference with which the public at large have commonly regarded these matters. It is, as already hinted, only when some great pestilence, as the Cholera, has plainly begun to signalize its access by fatal proofs, that the feelings of people can be warmly excited in their behalf.

Whatever the cause of this may be, we cannot agree with those who ascribe it wholly to ignorance. Men are often found, both ignorant and educated, who do not employ defensive means placed at their disposal, even when they well know that danger threatens. Take, for example, the case of workmen in coal-mines, when they neglect the use of the *Safety Lamp*,—sometimes even exposing the flame merely for the purpose of lighting their pipes. Take, again, an instance not uncommon before the more general introduction of Dr. Snow Harris's arrangements for protecting sea-going vessels from the effects of *lightning*; ships returning to port after encountering the hazards of numerous thunder-storms, whose officers made no trial of the complete sets of defensive apparatus with which they were furnished,—the very boxes in which they were stowed away on board having never been opened.

Of the phase of human character to which allusion is now made, every observant person's own experience would suggest examples more or less striking. As regards sanitary precautions, it may indeed, in part, proceed from a want of knowledge of the

facts concerned and the scientific principles involved. But it is unquestionably in a great measure due to, and sustained by, a feeling that the consequences of neglect *are not inevitable;* and there is also the well-known disinclination *to take any trouble* which circumstances do not appear to render imperative. Such as it is, however, the apathy referred to has proved a very great hindrance to the progress of sanitary improvements; and has, accordingly, been a fruitful source of complaint from those who have advocated them.

As preliminary to a discussion upon *Ventilation*, it would be useful to review the whole subject of sanitary undertakings, amongst which it enters as, perhaps, the chief of the processes recommended by science and experience for adoption throughout the community. We should thus, however, find ourselves called upon to notice topics too extensive and too various, and, it may be added, too important, to admit of their being profitably disposed of within limits at all consistent with our present purpose. We can only refer in a cursory manner, by way of introduction, to a few leading features; a glance at which may, as I trust, assist us in forming correct notions of the particular subject before us.

Good health, next to morality founded on religious principle, is the condition of most moment to man on earth. Equally essential to the rich and the poor, it is indispensable both to the acquisition and the enjoyment of all the material blessings of life. In comparison with the one consideration, *health*, what are all those objects so eagerly coveted by the man "with a sound mind in a sound body?" The laying up of stores of wealth; honorable rivalship in the various fields of industry; in mechanical skill; in the walks of literature and science; in the arts, trades and professions; in politics and public life,—how insignificant do all these things become in the estimation of the suffering invalid, who, in his cravings, contemplates only relief from bodily pain!

Now, every individual in a community who is capable of exercising his faculties may be able, to some extent, to guard against influences prejudicial to personal comfort and health, by the use of his own ingenuity and circumspection. But when we consider how numerous are the influences adverted to, what an extensive sphere of action they have, that they are often indiscriminate and

secret in their operation, we see that isolated or casual vigilance are totally inadequate. The most carefully devised plans of self-protection adopted by one individual or family, may be disconcerted through the ignorance, or the folly, or the culpable neglect of another. No man can live in any of the large centr of industry and commerce, without having his own health and that of his family perpetually endangered through the condition of adjoining localities and tenements. There may be, for instance, neglected drains or accumulations of rubbish in neighbouring streets and vacant lots. In every populous place there are necessarily numerous lodging-houses of all kinds; those of the inferior sort furnishing more cases of fever and other contagious diseases than any other class of dwellings. Over these, Small-pox, Typhus, Scarlatina, and Cholera, usually hover. They become the centres of morbific influence, which passes from street to street, from the humble abodes of the destitute poor to the houses of the industrious artizan and tradesman, and, penetrating the nurseries and chambers of the opulent also, spread distress amongst all classes. In fact, wherever the population is great, and regular inquiries have been set on foot for the purpose of investigating the state of health of the people,* the published returns shew conclusively that no individual can depend upon his own vigilance alone for the protection of his health from physical and really preventible causes of disease. Nothing short of systematic sanitary arrangements can suffice, carried out on a large scale, or at least on a scale that is commensurate with the progress of the community. Nor can such arrangements prove effectually successful without the co-operation, whether voluntary or otherwise, of all.

In order to infer that the prejudicial influences to which allusion has been made, must be prevalent *amongst ourselves*, we are not obliged to wade through the voluminous statistical returns published in the Old World. We need only to refer to our own

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* As in England, France, Austria, &c., whose legislatures have provided on a large scale for this object. For details of results as respects England, see reports of the Registrar General, the Poor Law Commissioners, Children's Employment Commission, Commission for Inquiring into the Health of Towns; also, reports on various towns, published in the Statistical Journal since the year 1839.

less perfect records, and to indications patent to every man's observation, to become assured of the existence of a vast amount of *bad health.* Let us resort to the last Canadian census, by which it is plainly shewn that the proportional number of deaths is *greater for cities and populous districts,* and that the ratio of mortality is *fearfully large for the earliest periods of life.*

A TABLE SHEWING THE POPULATION AND MORTALITY OF CANADA IN THE YEAR 1851.

	POPULATION.	DEATHS AT ALL AGES.	INFANT MORTALITY.
All Canada,.......	1,842,265	19,449 or 1 in 94	9339 * under 5 years of age.
Country Districts, .	1,678,154	15,739 or 1 in 107	7273 * under 5 years of age.
Town Districts, ...	164,111	3710 or 1 in 44	2066 * under 5 years of age.

A TABLE SHEWING THE POPULATION AND MORTALITY OF CANADIAN CITIES IN THE YEAR 1851.

	POPULATION.	DEATHS AT ALL AGES.	INFANT MORTALITY.
Montreal,.....	57,715	1725 1 in 34 living	859 under 5 yrs. of age.
Quebec, ...	42,052	1064 1 in 39 "	734 " " †
Toronto,......	30,775	474 1 in 65 "	245 " "
Hamilton, ...	14,112	172 1 in 8[illegible] "	104 " "
Kingston,.....	11,697	185 1 in 63 "	81 " "
Ottawa, ...	7,760	90 1 in 86 "	43 " "

* It will be seen from these numbers that the deaths of children under *five* made up *half* the mortality, and even more than that in the case of the cities.

† This excessive mortality among children, registered for Quebec for 1851, can perhaps only be accounted for by referring it in part to the prevalence (temporarily) of local epidemics affecting infants. Doubtless a large number of the deaths returned were those of emigrants soon after their arrival. It was not found convenient to procure a distinct return for the fixed population of the city.

It is admitted that these returns are imperfect on the very points now under notice, but the general facts are manifested clearly enough.*

* Some results deduced and calculated from the published returns of other countries, are here appended for the sake of general comparison and further illustration :—

	Annual mortality.	Infant mortality. Number of children (of 100 born) who die before 5 years of age.	Number of persons (of 100 born) who reach 70 years.
All England and Wales	1 in 46	26	14 †
" Town districts....	1 in 38	35	9
" Country districts..	1 in 55	20	20
London, (average)....	1 in 39		
Healthy quarters....	1 in 46	41	10
Unhealthy quarters .	1 in 30		
Liverpool, (average)..	1 in 29		
Healthy quarters....	1 in 41	50	8
Unhealthy quarters .	1 in 25		
Manchester, (average).	1 in 31		
Healthy quarters....	1 in 44	50	8½
Unhealthy quarters .	1 in 26		
Leeds, (average)......	1 in 38		
Healthy quarters....	1 in 42	49	7
Unhealthy quarters .	1 in 23		
Birmingham	1 in 38	47	8
Massachusetts, U. S., average	1 in 54	30	24
Towns	1 in 47		
Unhealthy quarters .	1 in 30		
Edinburgh...........	1 in 36		
Glasgow	1 in 31		
Aberdeen............	1 in 51		
France	1 in 42		
Paris	1 in 32		
Prussia.............	1 in 37		
Berlin............	1 in 34		
Austria	1 in 32		
Vienna............	1 in 22½		
Madrid..............	1 in 29		
Rome	1 in 25		
Sierra Leone.........	48 in 100		

All the above results deserve the most careful notice of all who have it in their power to promote the introduction and progress of sanitary improvements. The amount of mortality, as expressed by the numbers given, may also be assumed to furnish, in a general way, the relative extent to which disease prevails; the fatal cases being, of course, far less numerous than those which are not so. As respects the compara-

Another very noticeable fact is the enormous quantity of patent, or, as they are sometimes called, *quack* medicines now used in the community. Many of these, probably most of them, are taken in different varieties of malady, and in various stages of the same disease, and in doses which, it is to be feared, are but too commonly prescribed under the impulse of a wholesale cupidity. It is easy to see that they often become, in the hands of those who habitually employ them, mere weapons of offence against the laws of health. But it is impossible, perhaps, to suggest even an estimate of the extent to which recourse is thus irregularly had to remedies of this class. We know, however, that the consumption must be enormous. They are called for from all the chemists and druggists, as well as from the general dealers throughout the land. Witness also the profuse amount of agency, and of advertising in newspapers, pamphlets, and almanacs, which are sustained by the revenues of those who thus appeal to the ailments of a credulous public.

From such, amongst other sources of information, we are entitled to infer that *bad health* is very prevalent; not to speak of minor evils, such as mere discomfort, restlessness, languor, ill-humour, unrefreshing sleep, and a thousand other indefinite proofs of the absence of a vigorous bodily condition.

Now, although medical science has not furnished any satisfactory explanation of the modes by which various particular maladies are induced and propagated, yet we do know that the avoidance of many kinds of disease is possible through the use of precautionary measures. Experience has also shewn that disorders generally, whether infectious or otherwise, can be modified, their

tive salubrity of town and country districts, and the consequent influence on the physical capabilities of the people, we may take notice of the fact, that recruiting officers in England invariably pick the best and largest number of their soldiers from the rural districts. Military medical men also are well aware of the superior powers of endurance of men recruited in the agricultural parts, when compared with recruits from London, Birmingham, Leeds, &c.

† The numbers in this column afford data for forming a general idea of the relative duration of life in town and country districts, as affected by causes existent at the period when the returns, from which they are deduced, were made up.

malignant characters assuaged, and their duration and sphere of action limited, by having recourse to means within our reach and under our own control. An apparently trifling change of place, for instance, has often been seen to produce an entire alteration in the state of health of a body of troops. Simple precautions, as regards diet, cleanliness, and ventilation, on shipboard, have sufficed to cause the disappearance of the scurvy from modern navigation,—formerly an almost universal scourge to mariners. The introduction of a copious supply of water, together with adequate sewerage, and the cleansing and ventilation of the habitations of the poor, have, in numerous instances on record, suddenly and totally changed the character of districts remarkable for the prevalence of constant and malignant diseases. Some centuries ago, in European countries, the mortality, during what were called *unhealthy* seasons, has been estimated at *one sixth* of the whole population in the course of three or four months,—and even during periods when pestilence did not prevail, the ratio was as much as *seven or eight per cent.*; but in the present day in the *morbid* districts of those same countries a ratio of from *three to four* per cent. annually is reckoned to be fearfully high,—the decrease being mainly attributable to improved physical conditions such as have been alluded to.

The purpose with which these allusions have been made is not merely to point at the dependence of the public health upon external circumstances, but to suggest, in a general manner, some of the grounds for believing that a large amount of the disease, and consequent misery, witnessed in society springs from preventible causes.

It appears quite unnecessary to cite particular examples. Nor is it needful to make other than a general reference here to the influence exercised by moral in contradistinction to physical agencies. It must indeed be admitted that health, and the duration of life, in this transitory scene, are much affected by causes different from those named. Modern society is characterized, to an extent unknown in former times, by an increasing activity in the pursuit of wealth, by a prevailing eagerness to become suddenly rich or influential or famous in the world. The faculties both of mind and body are thus taxed to the utmost stretch of endurance,

and an amount of labor is entailed beyond the actual requirements of man's position and the wants of nature, such as cannot fail to abridge the span of life. We should note also, in passing, the additional strain occasioned by the excitement of highly artificial modes of conducting social intercourse, and by what is commonly termed *fast living*, which, even in the absence of gross moral depravity, tend to impair and waste the vital energies. But allowing for all these causes, and for the various accidents incidental, under any circumstances, to man in his necessary contests with the various elements appointed to exercise his natural powers, it may be asserted that they do not, comparatively speaking, constitute a very great portion of the sum total of influences adverse to personal comfort and health.

I have not alluded to a fact deducible from most of those regular inquiries into the conditions upon which the material welfare of a people depends. The moral and the physical agencies have invariably been found to *strengthen and react upon each other.* No language can adequately describe the utter degradation of those who, in some of the great centres of national industry, exist in crowded localities when sanitary precautions are wholly neglected,—where there is an entire absence of ash-pits, sewers, drains, and water-supplies, and of ventilation. Who can realize the consequent impurity, discomfort, and state of bodily disease? Who can rightly pourtray the sad picture when it is added, on unquestionable evidence, that there is also a constant violation of decorum, a blunting of the moral sensibilities, and every conceivable form of vice and depravity, together with an absolute indifference about health, or comfort, or better accommodation. But, it may be inquired, to what end are these statements and allusions introduced here? Because, it may be replied, the whole subject of sanitary affairs is one of painful consequence to ourselves,—amongst whom towns and cities grow up out of mere settlements far more rapidly than they used to do in the old world; so that unless we take to heart the lessons of experience elsewhere, we incur the danger of establishing in the earliest stages of our own progress the certainty of a long train of frightful evils. Upon a subject so serious it may fairly be called a duty to turn to account

every possible opportunity of agitating the public mind.* In the older countries of the world thousands of our fellow-beings annually fall martyrs to the neglect of proper regulations for the formation and healthful laying out of building-sites, streets, water-courses, and sewers, which ought to have been provided for during the earlier periods of the history of all large towns.†

* "........To this end it is not merely necessary that we should announce the momentous truths brought to light by our painful inquiries, but that we should insist upon them; that we should repeat line upon line, and precept upon precept, until even the most indifferent is aroused or softened, and a passive assent becomes an active living principle. No great truth was ever inculcated by being once said, and we are resolved to adhere to this momentous question until it has awakened that attention and activity which must result in effectual reformation."—*Artizan*, on the Health of the Working Classes in large Towns. See also note on page 9.

† In most large towns, it is to be noticed, there are what have been termed *healthy* quarters and *unhealthy* quarters,—the distinction having arisen from the greater frequency of disease and death in some localities. The unhealthy districts are usually those which are older, abounding in narrow streets, lanes, and alleys, nearer to the banks of canals or rivers, and situated at lower levels, so that of course the general drainage finds its outlets and termini amongst them, while in many cases they are liable to periodical inundations. Improvements with a view to greater salubrity are often well nigh impossible, on account of the vast destruction of property and other expenses that would attend the taking of any really effectual steps.

The wealthier merchants and professional men can, it is true, secure for themselves and families, some degree of immunity from the resulting evils, by erecting habitations on more elevated and distant sites, and in this manner, frequently arise the distinctions of *New Town* and *Old Town*, so common in Europe, as appertaining to contiguous portions of the same city.

Less than 20 years since an able writer, referring to Edinburgh, expressed himself, "It has the reputation of being a beautiful and singularly well-placed city, and has been termed the modern Athens. But this description only applies to the New Town, which has grown up within a century; whereas the Old Town consists of numerous closes, or *wynds*, diverging from High Street, and the houses are often so close together, that persons may step from the window of one house to that of the house opposite,—so high that the light can scarcely penetrate the court beneath. In this part there are neither sewers nor any private

For this reason, if for no other, their case ought to be held up on all occasions as a warning to profit by in all the flourishing localities of America, which may appear likely to become great centres of population, industry, and commerce. On the principles of humanity and self-interest, conjointly, it becomes a duty to conjure all persons of intelligence, property, and influence in such localities, to leave no exertions unemployed, that may tend to secure exemption from similar physical evils.

In America, however, even in towns that have already attained some magnitude, the carrying out of effective sanitary provisions is far more easily attainable than in the towns and cities of Europe. If we possess less of superfluous wealth to invest in the requisite works, we are, at least, not obstructed by the presence of a vast growth of population. We are not, as in Europe, impeded by a natural disinclination to meddle with habits and places and structures hedged round by historical reminiscences or consecrated by venerable antiquity. Take the example of London, which in former times was remarkable for the entire absence of sanitary precautions, the streets many feet below their present levels, irregular, crooked, and narrow, so that people on opposite sides could

conveniences whatever belonging to the houses; and hence the refuse occasioned by the presence of at least 50,000 persons is, during the night, thrown into the gutters, producing, in spite of the scavengers' daily labours, a state of things extremely prejudicial to health. Can it be wondered at that, in such localities, health, morals, and common decency should be at once neglected? All who know the private condition of the inhabitants will bear testimony to the immense amount of their disease, misery, and demoralization."

Mr. Chambers, in a letter to the Poor Law Commissioners, observes of them, "They have gravitated to a point of wretchedness from which no efforts of the pulpit, the press, or the schoolmaster, can raise them, for they are far too deeply sunk in physical distress, and far too obtuse in their moral perceptions, to desire advantage from any such means of amelioration."

Dr. Alison, in his work on "The Management of the Poor in Scotland," says, "The lodgings, houses, and closes of the Old Town are scarcely ever free from malignant fever; and, in the city itself, the mortality in a single year has been as high as 4½ per cent. (or 1 in 22). Nothing short of a pretty extensive demolition of the Old Town will stay the evil."

shake hands with each other. The resulting evils had reached a great height by the middle of the 17th century, without any serious efforts being made for their removal, so that in the end it was reserved for *the great fire* and *plague* of 1666 to pave the way for and inaugurate the enforcement of *some* sanitary measures. It is probable that no other imaginable means than such signal calamities could have served to vindicate the laws of public health.

Even in our Canadian towns, conflicting local interests, and a dread of the expense necessarily attendant upon the execution of works for sanitary purposes, are not unfrequently permitted to hinder their adoption or their progress. Of the consequences, the history of sanitary undertakings elsewhere, furnishes many sad examples. We learn that delay in endeavouring to grapple with and to vanquish these and the like difficulties at once, may amount only to staving them off until they entail upon ourselves or our successors evils impossible to be endured. Take again a single example from the case of London, where, at the present moment, measures are in hand for preventing the utter contamination of the Thames water. This result, proceeding from an imperfect system of drainage, was foreseen many years' ago; but to those, who have at this day to cope with it, the trouble and cost have become comparatively gigantic. One estimate after another has been suggested, until the anticipated expenditure has reached to upwards of twenty millions of dollars. It is as if the city of Montreal were now required to be taxed half a million of dollars in order to pay for the neglect to lay out a few thousands forty years ago.

Enough, perhaps, has been said to illustrate the general purpose of sanitary improvements; but if we examine the subject a little further, and with reference to particulars concerned in the practical execution of any system, this will be found to resolve itself ultimately into the carrying on of a species of warfare with the properties of *noxious gases*. Solid and fluid materials capable of evolving these—especially decaying animal and vegetable products—are required to be withdrawn from our vicinity, lest by exposure to the sun or atmosphere, they become sources of exhalations injurious to health. All kinds of refuse matter, in fact, must, on that account, be prevented from accumulating in the

streets, or in and about our habitations, whether they originate in carrying on processes in the arts or manufactures, or in the proceedings of daily domestic life. For a like reason, even water which has descended from the clouds, or which may have remained behind after the subsidence of an inundation, cannot be suffered to remain stagnant; for if not quickly removed, through artificially constructed channels or otherwise, its evaporation serves as a vehicle both for diffusing a hurtful dampness, and for spreading through the air we breathe many unwholesome substances which it previously held in solution.

The requirements, therefore, of a considerable town create a necessity for adequate sewerage, together with abundant and continuous supplies of pure water, as well for all detergent purposes* as for absorbing and carrying off all products that might by decomposition originate such emanations as have been mentioned.

Then there is to be dealt with an unceasing and prodigious flow of poisonous vapours, arising from combustion, from the respiration of living beings, and exhalation from the surface of their bodies.

To devise plans for establishing such arrangements, to execute them, and to adjust the general system to the wants and peculiarities of every street and every individual habitation, to secure

* The purposes here indicated as objects on account of which an adequate system of *water-works* is required to be established in every town, village, and habitation, are not so generally appreciated as they would be if the unnecessary waste of human life were regarded with the same hearty concern as the destruction of property by calamitous fires. Yet it may be asserted, that the actual loss occasioned by the latter is not nearly equal to the sum total of what society at large suffers from the neglect to supply water *copiously, at any cost.* With that essential tributary to the means of purification, conveniently furnished in all our streets, lanes, and houses, the community might save much that is now expended in other ways,—in sustaining various institutions, medical and others,—in repressing crime,—in supporting or assisting the destitute survivors of those who perish prematurely. Who can pretend to estimate the mere pecuniary loss annually inflicted by the unnecessary abridgement of valuable lives, or through the unnecessary impairing of those energies in thousands upon which depend the useful exercise of labour, skill, and intellect in the various callings?

such universal co-operation and attention to details as are requisite to their full success, and, finally, to reconcile men's minds to the outlay needful, which can only follow upon an established conviction of its necessity,—constitute, in all, one of the most important and complicated problems of our times.

CHAPTER II.

ON SOME OF THE PROPERTIES OF MATTER IN THE GASEOUS FORM.

It will be seen from what has been stated that the grand object of a sanitary system is to maintain the purity of the surrounding atmosphere, on the one hand by preventing, if possible, the influx of deleterious gases, and, on the other, when the access of these cannot be hindered, by neutralizing them as fast as they are generated, or by causing their immediate escape from our vicinity. Gases, besides being usually invisible, and therefore capable of being inhaled unawares with the air we breathe, are all remarkable for the disposition to spread themselves throughout each other. Two or more of different kinds, when introduced together into any given space, thus diffuse themselves without respect to their relative weights. After a time the intermixture becomes complete, each occupying, as it were, the whole space, just as if it had entered a vacuum. The process appears to be prevented from being instantaneous only by the collision of each other's particles. This very striking property of the gases must not be confounded with what is commonly termed their *elasticity*, or at least must be taken account of independently of that quality, which relates to mere expansion without reference to their diffusion or spontaneous intermixture. It is very important, as regards our present topic, to comprehend rightly the nature of this property. To exemplify it, let us imagine two closed vessels filled respectively with *carbonic acid gas* and *common air*. A communication between the two being made, through a small tube or otherwise, the gases pass into each other in such manner that both vessels become filled with a *uniform mixture* of carbonic acid and air. If *hydrogen gas* were employed instead of air, the same result would occur. Even if the hydrogen were contained in a vessel placed vertically above the other, it would move *downwards*, and the carbonic acid *upwards*, to effect the mixture; although carbonic acid gas is twenty-two times the weight of hydrogen. This result, so contrary to what might be expected from

the operation of gravity, becomes the more striking when we contrast it with what would take place if liquids—as, for instance, *oil*, *water*, and *mercury*—were placed together in a vessel. The heaviest body would then sink lowest, and the highest would be found floating uppermost.* The fact is well illustrated by the case of the atmosphere, for the several ingredients,† although differing considerably in weight, are always found, on trial, to be thus uniformly diffused through each other, from the surface of the earth to the highest attainable elevation. In one sense the several gases may be said to be in a manner *dissolved* in the substance of each other, each, however, preserving its own distinctive characters in every part of the mechanical mixture thus produced. By means of some such process as that here described, the air in an apartment becomes tainted throughout when a noxious gas is present in sufficient quantity, while out of doors the effect is speedily to dissipate and thus neutralise any vaporous body that enters the atmosphere.‡

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* The phenomena here noticed have been investigated by many distinguished natural philosophers. Dr. Dalton, one of the great fathers of modern Chemistry, was the first to set up a rational theory on the subject. He explained the process by considering that the space occupied by a gas becomes, with respect to another gas, in some sense, a *vacuum*. Dr. Faraday, Dr. Graham, and the late Professor Daniell, may also be named as having, at more recent periods, examined the subject experimentally with the greatest skill and success. By these gentlemen it has been shown, that the diffusion occurs when the gases have no other opportunity of passage than that afforded by the smallest cracks or chinks in the containing vessels; also through intervening porous substance, as paper, *moistened animal membrane*, or plugs of plaster of Paris. The facts become extremely interesting and important in reference to physiological phenomena, especially those presented in the processes of respiration. See also the remarks on respiration further on.

† Essentially oxygen and nitrogen gases, together with a comparatively minute portion of carbonic acid gas.

‡ In offering these remarks, it is not intended to suggest the idea that the introduction of a comparatively *heavy* gas (as *carbonic acid*) into a space already occupied by another (as common *air*), would not, in the *first instance*, be followed by an expulsion of the lighter fluid, or at least by a greater accumulation of the heavier gas in the lower parts. Thus, carbonic acid gas, when poured over a lighted taper, immediately

It is important also, especially in a physiological point of view, and in connection with the subject of ventilation, to note particularly the *comparative facility*, or rather *the rapidity*, with which matter in the gaseous form *finds its way to and acts upon the sources of vital power*. The most familiar instance, perhaps, is that furnished by the inhalation of *tobacco fumes*. *Opium* also, *iodine*, *mercury*, and a great many other substances, when rendered vaporous by heat, are found to affect the animal functions far more rapidly than the same bodies when introduced into the system in their customary solid or liquid forms. *Ether* and *chloroform* may also be mentioned, now so extensively employed in medicine in cases where it is an object to produce a speedy insensibility to pain.

But we have, if possible, still more decisive proofs in the inhalation of gases whose effects are deleterious, the most remarkable being compounds of *hydrogen*.

Arseniretted hydrogen (formed when an alloy of *zinc* and the metal *arsenic* is submitted to the action of acidulated water) quickly causes death when breathed in the minutest quantity.

*Sulphuretted hydrogen** in like manner is very potent. It is

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extinguishes it. Again, carbonic acid gas is sometimes found nearly *pure* in old wells, &c.; and in certain cases possibly the air in the lower parts of a building used for public assemblies may become sensibly tainted before the effect has become oppressively disagreeable in the galleries, in the absence of ventilation. In the two latter cases, however, it is to be recollected that the carbonic acid is in continual process of generation, while *time* is required for the complete diffusion referred to in the text. It is quite natural to expect that the more immediate effects of the noxious gas should be encountered at and near to its source, or in those parts into which it enters in a mass through the sudden action of gravity, as in the case of the extinction of the lighted taper. All, in fact, that is here contended for as worthy of particular notice in connexion with the subject of Ventilation, is, *the established principle of diffusion throughout each other's substance whenever heterogeneous gases are present and in communication with each other.*

* This is the principal gas rising from drains, cesspools, &c. To prove its destructive qualities, it has been injected into the veins and chest and beneath the skin of animals. Two or three cubic inches employed in this way were found to destroy smaller creatures, as cats, rabbits, &c., *instantly*. A rabbit was immersed in sulphuretted hydrogen to the neck,

said that air containing sulphuretted hydrogen to the extent of 1-800th part suffices to kill a dog, and that when 1-250th part is breathed by a horse, even this large animal soon succumbs. *Carburetted hydrogen** also is another very deleterious gas when taken into the animal system. Of *carbonic acid* frequent mention is made in the following pages as being produced whenever the processes of combustion and respiration take place. Its effects are *immediately* injurious, and the amount of injury caused is proportional to the extent of its admixture with the air breathed.

Now when we consider the peculiarities of gaseous bodies which have been mentioned, their *invisibility*, their *spontaneously diffusive power*, and their *speedy action* upon our bodily organization, we cannot fail to perceive the risks we run whenever we neglect to adopt such measures as may be requisite in order to secure their absence from our vicinity†. We must see that we are

and died in ten minutes, though allowed to breathe the pure atmosphere. Nine quarts of the gas were injected into the intestines of a horse, and the animal fell dead in *one minute*. Children and even adults have frequently fallen victims to this poisonous substance on the occasion of drains being incautiously or accidentally opened. Breathed in a state of dilution it is excessively injurious to health.

* This gas is produced in our stoves, and also when common coal is burned. It is lighter than air at the same temperature. On the animal system, when inhaled, it produces immediate sensations of *sleepiness*, accompanied with extreme sense of weakness. In Duglinson's Physiology it is stated, "It is very depressing to the vital functions. Even when largely diluted with atmospheric air, it occasions vertigo, sickness, diminution of the force and velocity of the pulse, reduction of muscular vigor, and every symptom of diminished power."

† It may not be out of place here to allude to the absorbent power possessed by bodies, solid and liquid, in virtue of which a gas is sometimes enabled to permeate their substance. Our food and drink may thus imbibe hurtful qualities from mere exposure to unwholesome air. The effects upon milk, butter, meat, bread, &c., are well known, being soon appreciable from the changes of flavour produced. Our clothing, too, articles of merchandise, &c., are in like manner susceptible of being rendered the vehicles of deleterious matter, so that causes of contagious maladies may, by their means, be transported from place to place. In some important sanitary proceedings it is considered so difficult to dislodge the morbific agents thus introduced from beyond the sea, that recourse is occasionally had to the destruction of property of value, lest it should become a source of wide-spread disease.

surrounded by influences grievously inimical to health whenever we suffer ourselves to remain in situations where we are *obliged* to inhale them. Yet such is always the case whenever we voluntarily remain in confined apartments; whenever we do not provide specially for the ingress of fresh air and the escape of that which has been vitiated. As I shall have occasion to refer to these things several times further on, I shall only add here that the wonder is so many of us escape so long with comparative impunity, when we reflect upon the continuous character of the sources of impurity amidst which so many of us are content to pass our lives. If sulphuretted hydrogen and carbonic acid gas be really injurious to health, and in certain cases destructive of life, then surely it becomes worth our while to cherish at all times in our minds a lively appreciation of the fact that these very gases are ever present to afflict us, and that they will afflict us *unless we take measures expressly for preserving the purity of the air we breathe.* They are not only evolved copiously in our streets from drains, cellars, &c., but they also emanate from most forms of decaying vegetable and animal matter. They are produced within our own bodies, in our stoves and fireplaces, and, in short, wherever the processes of life and combustion go on.

There have been mentioned only a few of the properties of gases,—of those more prominently concerned in our present inquiry. But there are, as may be supposed, various other qualities, a notice of which would appertain to the subject. It would be well if, for instance, we could here set forth the facts relating to the mechanical and chemical characters of the more common gaseous bodies, especially *atmospheric air*, *carbonic acid*, and *watery vapour*. The laws of gaseous motion, the laws of their *expansion* by means of *heat*, and also with reference to hygrometric and electrical conditions. A full consideration of these things, however, would scarcely accord with the requirements of a popular discourse; though the want will be found to be, in some measure, supplied by the tabular statements and brief incidental notices which occur afterwards.

CHAPTER III.

ON SOME PHYSIOLOGICAL AND OTHER CONSIDERATIONS CONCERNED IN PROCESSES OF VENTILATION.

It appears that the fabric of the human body is dependent for the healthful action of all its organs, and for the maintenance of life itself, upon the *continuous supply* of nutriment to every part of the system, as well as the *continuous removal* of various effete or refuse ingredients generated within it. The transfer of the materials of nutrition throughout, after they have undergone the digestive action, and an important part of the duty of draining off, as it were, products no longer useful, or such as have resulted from various internal processes, are performed by means of the *circulation of the blood.* Constituting about one eighth or one ninth of the entire ponderable substance of the body, it may be conceived to receive its onward impulse from one set of vessels in the heart, through the *arteries*, towards the remotest extremities of the system, whence it returns again in the *veins* to be propelled by another set of vessels towards the *lungs*, from which it retires to its former place of departure, to be again sent forth as before. The movement never ceases for an instant during the longest life. In its course from the heart, the blood receives into its current the materials for nutriment dropped into it from appropriate vessels communicating with the digestive organs; which latter are themselves sustained in activity and health by what they derive through other vessels from the great circulating medium. At the lungs, the matter of the blood is, as it were, *thinned out* in contact with the interior membranous surfaces or walls* of myriads of cellular spaces, which constitute together the chief volume of the lungs, and are placed in groups, of many thousands in each, around the ends of what are technically termed the *bronchi.* The Bronchi

* It has been calculated that as many as 17,700 air-cells are distributed about the end of each terminal bronchus, and that the total number of cells is not less than 600 *millions.*

communicate in tubular passages with the *trachea* or *windpipe*, through which the atmospheric air is inhaled from without, and thus brought into contact with the surfaces of the above-mentioned cells, but on an opposite side, so that an indefinitely thin membrane intervenes between the blood and the air. In conformity with a law of gaseous action, noticed in the preceding chapter, gases are thus enabled to pass from the blood *outwards*, and from the atmosphere *inwards*. In fact the actual result of the respiratory process, is, that at every *inspiration* of air through the windpipe a portion of its *oxygen* passes by *diffusion* into the blood; while at every *expiration*, gaseous matter, previously in the blood, is ejected through the same channel, together with the air thus altered by the partial absorption of one of its essential ingredients. The expiratory act is attended with an accompanying surplus of watery vapour, generally more or less charged with particles of animal substance derived from the moistened coating of the lungs, throat, and fauces. In this manner, and at the *rate of twenty or more times a minute*, supplies of oxygen gas are introduced into the system; and at the same rate, products necessary to be removed from within find an outlet.

By the process, thus familiarly* described, the blood is understood to suffer important changes at the instant of its arrival from the heart into the lungs. But it is believed that the greater portion of the oxygen absorbed is carried bodily in the circulation to all parts of the fabric; being distributed, as required, in minute quantities, until, by the time any given portion of blood returns to the lungs, the free oxygen has disappeared, and the circulating fluid itself is charged with the products already referred to. One chief use of the oxygen is understood to be the consumption of animal tissue, and of the minute vesicles and organs by which the internal functions are performed, but which lose their vitality in the act, their substance combining with the gas so as to form *carbonic acid*, and in part creating and sustaining the animal heat through the combustive process incessantly kept up by its instrumentality. By referring to the tabular statements given at the

* It is thought that the present purposes of description are best served by avoiding as much as possible the use of technical terms and by consulting brevity.

close of this section, it will be seen more precisely what quantities of *atmospheric air*, *oxygen*, *nitrogen*, *carbonic acid gas*, and *watery vapour*, are concerned in the exercise of the function of respiration, and also the extent to which the contiguous air is liable to be rendered unfit for breathing by each respiratory act.

Resuming, for a moment, the subject of the *Circulation*, it may be summarily repeated that its appointed function is four-fold. In the first place, it transports, through appropriate channels, to all parts of the body, the materials for structure,—the various tissues having the power of absorbing from this liquid the particular components of their substance.

Secondly. The circulation answers the purpose of carrying off, in the current of the blood, all the products of decay of the various tissues, and the different excretory matters which are set free in the course of the nutrient operations,—carrying these to their proper outlets, partly to the skin,* but chiefly to the lungs.

Thirdly. The circulation serves as the means of introducing oxygen gas into the system, the union of which, with the carbon of the tissues and fluids of the body, produces *carbonic acid*, eliminated† as described above.

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* The materials emitted every minute by cutaneous exhalation are found to weigh from 9 grs. to 26 grs., and consist of aqueous vapour mingled with decomposing animal substance.

† It may here be remarked, on the best physiological evidence, that there can be no cessation in the process of eliminating carbonic acid, without *death* ensuing in a very few minutes. When, however, only partial intermissions occur from any cause, or mere hindrance to its continuous evacuation, in the complete manner demanded by the wants of the system, then carbonic acid accumulates in the blood, and causes uneasiness and indisposition, according to the circumstances of the case.

Experiments have been made upon the effects of external heat and cold, and of the presence of an excess of carbonic acid in the external air, with a view to ascertain, how far the eliminating process is facilitated or obstructed by such causes. Messrs. Allen and Pepys, among others who might be referred to, after a series of elaborate investigations, determined that the presence of even a minute excess of carbonic acid in the air breathed, interferes materially with its excretion from the blood through the lungs. But the effect of cold, is to augment the amount discharged; hence may be inferred the resulting injury to health, when the demand for excretion of carbonic acid is rendered

Fourthly. The blood thus transports the means of generating, and diffuses *the animal heat*,—or at least is understood to be the principal agent in the process.

Of the function of *digestion*, it does not seem absolutely necessary to occupy time in particular description. It may suffice for our present purpose to state, summarily, that the three great physiological operations of *respiration*, *circulation of the blood*, and *digestion*, are each tributary to the healthy continuance of the other,—and so bound up with each other, that the cessation of any one is necessarily contemporaneous with that of all: and finally, as respects the circulation, if, through any cause, a sufficient supply of oxygen gas is *not* furnished through the lungs from without, or if deleterious gasses be inhaled through the windpipe, and thence partially imbibed by the blood at the lungs, then every fibre, tissue, and organ within the body,—the nerves, the brain,* the heart, the stomach, the lungs, and the blood itself, are subjected to immediate injury.† The result may be mere inconvenience, or it may be disease, or, in extreme cases, death.

A little attention to the foregoing particulars, and a reference to those which are stated in tabular form at the close of this section, would convince any reflecting person how desirable it is, how necessary to the preservation of good health and bodily comfort, to provide effectually for the two-fold purpose of "Ventilation." Whatever the particular processes may be which are adopted for its accomplishment,—whatever the cost,—we must both have the pure atmospheric element to breathe, and also be freed from the presence of vitiated air and of all gaseous matter unfit for respiration. The products of respiration, leaving the body at a temperature of about 90° Fah., and those of combustion, passing from their sources at a much higher temperature, naturally move upwards, in obedience to the force impressed upon them by the heavier surrounding medium. But as they vitiate the latter in

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greater than usual by one external cause, and the capability of exercising the function, is, at the same time, diminished by another.

* It is calculated that about *one sixth* part of the whole blood is transferred direct from the heart to the brain.

† The *rate* of circulation is estimated at 160 *seconds*, or less than 3 *minutes*, for each complete round.

much larger volume than their own, and, on cooling, as well as by the principle of diffusion, are likely to come down again and spread around us when we are within doors, in our houses, where those products are continually in process of formation, we can never feel free from the danger of inhaling them again, unless special means are provided for their constant removal and ejection into the atmosphere without.

The *fitness*, however, of air for respiration does not wholly consist in its purity—It is additionally requisite that it should be at a congenial temperature,* and that it should be neither too damp† nor too dry, to suit the wants of the system.

There is also another condition to be satisfied, which is implied in what has been already stated, but which it is important to mention expressly. The *quantity* of air supplied by the ventilating-process must be regulated by the varying exigencies of each occasion, so that an ample amount may be furnished as well for breathing purposes as for those of combustion, and other coincident processes in which oxygen may be consumed or the air rendered impure.

A perfect system of ventilation would therefore imply the fulfilment of all the foregoing conditions, as respects the *quantity*, *quality*, and *temperature* of the air supplied, together with the *complete and immediate removal* of that which is vitiated. The existing state of domestic architecture, however, in this country, is discouraging enough, in view of the attainment of such a system. Small indeed is the number of habitations erected, whether under the superintendence of their owners or that of architects, in which the object receives any attention whatever. As it is intended to devote the subsequent section to the consideration of various methods which are in use, or which have been suggested, I may be permitted to occupy the remaining portion of this chapter with some general remarks upon the state of things consequent upon the neglect just alluded to.

* The temperature most generally acceptable is about 65° to 70° Fah.

† When the moisture of the air is estimated by means of two thermometers, the amount indicated by a *difference* of 5° between the temperatures of the dry and wet bulb may be regarded as not unsuitable—a greater difference than that would be admissible—but a less difference would shew too much moisture.

In our rigorous climate, during several months annually, owing to the prevalent mode of heating, and the disposition of people to *shut themselves in* with all the assistance that can be derived from the use of double walls, doors, and sashes, to *keep out the cold air*, we are indebted for what good health we do enjoy, and even for the preservation of our lives, mainly to the imperfections that attend the best workmanship. It has been calculated that about 7 or 8 cubic inches of air pass, per minute, between the junctures of the closest fitting ordinary window-sash, when the difference of internal and external temperature is about 20° Fah. If we take also into account the opportunities afforded along the tops, sides, and bottoms of doors, not to speak of other accidental fissures or openings, we see that, in spite of ourselves, the continuous ingress and egress of air, are to some extent secured. The various kinds of powerful heating apparatus which are in use in this climate, maintain also the strong drafts necessary to supply the incoming air in quantity sufficient for their own rates of combustion, although they do not and cannot, without expressly contrived arrangements, furnish all that is required for the other purposes of consumption existent in every household. The increased demands which constantly occur in the intercourse of social life,—parties, balls, meetings, and so forth,—additional fires, gas-lights, and other means of strong artificial illumination,—suggest painfully enough some of the consequences which must result, during our Canadian winters, from our possessing in our habitations no other than those fortuitous methods of enforced ventilation.

In the humbler abodes and workshops, and, with very few exceptions, in the schools and dwelling houses of the people all over the country, the same *hap-hazard* modes of living prevail, as respects the prime essential of health and life, *fresh air*. Although it may not be possible to trace each distinct case to its true origin, yet it cannot be denied, that defective ventilation alone, in our homes and schools, is a fruitful source of inconvenience and injury to health,—of aggravated suffering and premature death. If some live to see the age of 70, 80, or 90 *years*, and would probably live longer still were all kinds of sanitary precautions effectually carried out, it has been seen that only about ONE HALF of the whole number of human beings born in Canada, whether in town or

country, attain to the age of FIVE YEARS. *It seems quite consistent to attribute this mainly to the want of ventilation, because it is precisely in the case of those infant victims that there is most confinement within doors, united with an inability to think and act for themselves, or to furnish any intelligible clue to the cause of their sufferings.*

One of the most remarkable, as well as dangerous, incidental accompaniments of defective ventilation is the imperceptible manner in which, even in the worst instances, the mischief operates. Our senses scarcely suffice to afford us the means of becoming sensible of the danger after we are fairly immersed within its influence. Let a person, during the night, or early in the morning, pass from out of doors into an occupied, or recently vacated, sleeping apartment. If there be no provision for ventilation, the bad quality of the damaged air within becomes instantly obvious. But after the first few moments, the inconvenience arising from disagreeable sensations diminishes, and, ultimately, almost ceases. A return to the open air, followed by a repetition of the visit, is attended with the sames series of sensations. The same peculiarities may be observed daily in dwelling-houses, schools, workshops, and in most places liable to continuous occupation.*

The watchful guardianship of the senses being thus partially or wholly supplanted, we can scarcely feel surprised at the apparent indifference to the need of ventilation so often witnessed. Many occupants of workshops, as well as many who inhabit decent

* The peculiarity has been occasionally mentioned by authorities on sanitary matters, although, I think, it has not been sufficiently urged. Dr. Reid, Mr. Tomlinson, and others have named it cursorily. In the letters addressed to the Poor-Law Commissioners in England, we find it often alluded to, and sometimes rather forcibly. One gentleman (chaplain of the Bath Union) thus speaks of it: "Let a man remain, even for a short time, in a close, pent-up room, sickening from the smell, and the perception of closeness will so entirely vanish, that he will almost fancy the atmosphere has been purified since his entrance. If, then, such are the effects of an hour in blunting our refined sensations, and rendering them insensible to noxious exhalations, what must be the influence of years on the perceptions of the working man? All who have the requisite experience will testify that the last want felt by the dirty is cleanliness."

houses and are not remarkable for disregarding obvious claims upon their attention in most of the common concerns of life, are thus undoubtedly under the influence of habitual adaptation to the consumption of inferior air. In country school-houses, of Eastern Canada especially, where 40 or 50 scholars, and even larger numbers, are often crowded into rooms about 20 feet square, with door and windows closed, and the interior maintained at a temperature of upwards of 80° Fah., it is no uncommon thing to notice an entire want of perception of the mephitic character of the air; teachers and taught alike, and visitors too if they remain some time, unconsciously breathing the same products over and over again.

The remarks which have been made respecting the absence of ventilating arrangements in Canadian houses, refer mainly to the winter season; at which period, as will be seen, the means of executing them economically, and of regulating them, by contrivances almost self-acting, are certainly more available than at times when domestic fires are not maintained. During these latter periods—in the summer, for instance, and early autumn—they are at least equally necessary for the preservation of our health, especially in the night time, as well as in such states of the weather, and in such situations, as do not admit of the ordinary facilities offered by the use of doors and windows. In short, it may be confidently stated that a system which shall satisfy all the conditions and requirements, under all the varying circumstances that present themselves for allowance, and at all times and seasons, is a desideratum which is far from being supplied in this country; although, undoubtedly some progress is now being made, by which, through the introduction of improved heating arrangements, it may be hoped that the evils noticed will be at least partially remedied.

In the following chapter some more practical details will be furnished in relation to the conditions to be satisfied by any system that can be deemed effectual; and in the meantime some numerical statements, previously referred to, are appended in this place:—

Table of Relative Weights of certain Gases.

Common air	1.000	14½
Oxygen	1.111	15
Hydrogen	0.069	1
Nitrogen	0.972	14
Carbonic acid	1.527	22
Sulphuretted hydrogen	1.180	17
Carburetted hydrogen	.972	14

In the first column of numbers the weight of oxygen is taken as the standard for reference; in the other, that of hydrogen.

Constituents of Atmospheric Air.

100 parts of air contain,—

Oxygen	21 parts nearly (*by weight.*)
Nitrogen	79 " "
Carbonic acid	.05 part "
Watery vapour	variable.

Table showing the Quantities of Watery Vapor retained invisibly in the Air, by which it is saturated.

Temperature.	Saturating Quantity.
32° Fahrenheit	2.3 grains per cubic foot.
40° "	3 " " "
50° "	4.1 " " "
60° "	5.75 " " "
65° "	6.7 " " "
70° "	7.75 " " "
75° "	9 " " "
80° "	10.5 " " "
85° "	12 " " "
90° "	14.1 " " "
100° "	19 " " "

According to this table, and the statement previously made, air for respiration at 65° Fah. should not hold so much as 5¾ grs. of water in suspension, this being the saturating quantity for 60° Fah.

Respiration of Adults (average results).

Number of respirations	20 per minute.
Air inhaled at each inspiration	20 cubic inches.
Air inhaled per minute	400 cubic inches.
Oxygen inhaled at each inspiration	4 cubic inches.
Oxygen inhaled per minute	80 cubic inches.

Products expired,—

(1.) Damaged atmospheric air, with nitrogen in excess.
(2.) About 15 cubic inches carbonic acid.
(3.) About 3 grs. watery vapour, impregnated with carbonic acid and decaying albuminous animal substance.

Surrounding air vitiated by mixture with the products of respiration .... 2½ cubic feet per minute.

Results of Sir Hmmphrey Davy's Experiments on himself.

Oxygen required in 24 hours	45,504 cubic inches.
Carbonic acid eliminated in 24 hours,	31,680 cubic inches.
Containing of pure carbon.........	4,853 grains.

Results of Experiments by Dr. Southwood Smith on Respiration and the Circulation of the Blood.

Volume of air ordinarily in the lungs..........	12 pints.
" " received at one inspiration	1 pint.
Volume of air inspired during the time of one circulation of the blood	48 pints.
Blood which flows to the lungs at every action of the heart............................	2 ounces.
And which is acted on by the air in less than ..	1 second.
Total blood in an adult..................about	24 lbs. or 20 pts.
Oxygen taken in in 24 hours.................	33 ounces.
Carbonic acid excreted in 24 hours ......about	18 cubic feet.
Pure carbon expired in 24 hours ....about	10 ounces.

Table shewing Products of Combustion of certain Substances, and the Extent of Action on the Air.

Products of combustion of coal, coal gas, and wood	Carbonic acid, nitrogen, aqueous vapour, and carburetted hydrogen.
Products of combustion of oil and tallow ....chiefly	Nitrogen, aqueous vapor, and carbonic acid.
Combustion:	
1 lb. of coal requires for combustion and accompanying waste of air	200 cubic feet of air.
1 lb. of tallow vitiates ...about	170 cubic feet of air.
1 cubic foot of common coal-gas vitiates ....about	10 cubic feet of air.
And produces.....about	1 cubic foot carbonic acid.
Together with ....about	670 grs. of aqueous vapour.
Which is enough to saturate	100 cub. ft. of air at 65° Fah.
1 lb. of charcoal consumes all the oxygen in.......about	175 cubic feet of air.
Vitiating besides ..about	500 cubic feet of air.

CHAPTER IV.

SOME FURTHER DETAILS RELATING TO THE CONDITIONS TO BE SATISFIED IN THE VENTILATING PROCESS; AND ON SIMPLE CONTRIVANCES FOR VENTILATION.

1. The accomplishment of a ventilating process has been stated to consist in an adequate provision both for the *ingress* of respirable air, and the *egress* of that which has been vitiated or rendered unfit for respiration. It is evident that unless the latter object, *egress*, be secured, neither can the former. We can no more make air to enter a room without causing the exit of gaseous matter from within, than we can pour more water into a bottle already filled with that liquid. There must be in fact, in obedience to the laws that govern the mobility and equilibrium of the atmosphere itself, a perfect accord between the rates of motion and quantities of the effluent and in-coming gases.

It is therefore not enough merely to throw open a door or a window, although by so doing the air in a house or room becomes in time sensibly changed. An actual *movement* is needed, consisting in one part of air and gases moving outwards, and in another of the fresh entering air. This is a very important condition, and practically one which it is often difficult to secure or to regulate. Connected with it are various other questions of a practical nature; such as the dimensions and forms of the necessary openings, the situations in which they should be made, and the means of adjusting them to the ever-varying occasions for their use.

Some of these apparently minor concerns are often dealt with by those who do attempt to ventilate their tenements, just as if they were to be regarded as mere matters of taste. But unfortunately they cannot be so disposed of. They can only be determined upon practically by the instructed architect, or by one who is at least conversant with the laws of gaseous action and the other scientific principles involved.

It is also obvious that the dimensions of the openings required for ingress and escape, the forms of the conducting channels, the velocities and the quantities of the moving gases, must be all connected with and mutually dependent upon each other. We see, therefore, that these things become the subjects of numerical calculation based upon physical laws, which may not be dispensed with if the hope be entertained of attaining to a perfect system of ventilation.

Now it happens that the laws of gaseous motion as respects the mutual relations of temperature, density, velocity, friction, and the dimensions and forms of the channels, are amongst those parts of science that are least perfectly understood. Theoretical science therefore fails to furnish all the aid that would be required, and it becomes all the more necessary on that account for every one who desires to ventilate his house properly, to consult a competent architect as to the best mode of arranging about the above particulars.*

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* The dimensions of an opening and the velocity of the entering or effluent air being known, the *quantity* that would pass *per minute* is of course readily determined by an arithmetical operation. In practice, the dimensions can be measured, and so also can the quantities, though less easily, be estimated, and thence the actual velocities, and, in the end, the retardation from friction. But in practice the determinations thus arrived at in several cases are not found to present a clue to any general law sufficiently precise to be applicable in all, so that approximations only are made to supply the want of certainty. Experiments on a large scale have frequently been made with a view to determining the relations of dimension, velocity, quantity of effluent gas, friction, and amount of impelling force, but always with variable and uncertain results. In one instance, when the actual quantity of air concerned was known to be 14,726 cubic feet, the various results calculated from five different recived modes of approximation, were to be obtained from the numbers 16,159, 15,555, 15,152, and 5,017, respectively, upon each of which, the *very same allowance* for friction being made there would arise corresponding discrepancies.

It appears unnecessary to go further into such particulars, but I may here allude to formulæ and rules given by Tredgold, Sylvester, and others, and also to an easily computed process of M. Montgolfier, employed in common cases, in which these relations become the subject of necessary calculation, and which are understood to furnish tolerably correct approximations, as far as they are needed.

As respects the quantity of air required to be supplied for respiratory purposes alone, the statements which have already been made are perhaps of too general a character to permit our passing immediately to other topics. Until quite lately, and even now, in the great majority of cases, the practical question has been disposed of by reference solely to that bulk of air which might be assumed to continue on the whole fit for respiration during the period of occupancy; as, for instance, to allow so many cubic feet to each person. In these cases the authoritative customary quantum has been variously rated at from 800 to 1200 cubic feet, taking for granted that the continuous occupation will not last longer than seven or eight hours without measures being taken to change the air within completely. The late Sir C. Napier—emphatically styled the "soldier's friend" on account of his uniform attention to the wants and comforts of the private—used to contend for a minimum of 1000 cubic feet of space per man in barracks. The best physiological authorities appear to agree upon about 800 cubic feet as the minimum which can be arranged for with safety to individuals in prisons, work-houses, schools, factories, and so forth. The estimates of this class, however, are principally made with reference to the nocturnal occupation of apartments. In many of the sleeping chambers in hotels in Canada and the United States, the capacity does not exceed from 1200 to 2000 cubic feet, without, in many instances, any provision whatever for supply of additional fresh air or for the escape of the vitiated.

Now such estimates are undoubtedly those which experience has shewn on the whole to suffice without entailing an intense perception of inconvenience or of injury to health. Yet the method altogether may be confidently pronounced to be fallacious. At a rate of vitiation of only 2½ cubic feet per minute, the amount, in a close apartment, occupied during about eight hours, would render the air of a space of the above dimensions unfit for respiration. But for a peculiarity mentioned in a preceding page, the occupants would find the resulting inconvenience unendurable. Admitting that through unavoidable crevices about the door and window the external air must produce some changes in that of the room, still these can only be very partial, and altogether insuffi-

cient to hinder the diffusion of carbonic acid, in excess, from being complete throughout the limited space. During a cool night, that poisonous substance must pour down again about the sleeper, not long after it has been exhaled from his body.

This plan, however, of estimating the requisite quantity of air by the number of cubic feet around, is, practically, that which is adopted by persons who erect buildings without making special arrangements for ventilation. As has been said, it is, for the most part, the only plan in use. I can state, on the authority of a talented architect of this city, where already,* as I am informed, measures are in progress for the erection of more than 500 houses during the incoming building season, such arrangements are seldom or never called for by those who invest their money in house property. Instead, however, of settling the question of how many cubic feet of breathing-space should be allowed, it would seem to be our interest to take it up in another way altogether, by bringing to bear upon it a knowledge of the laws of nature, common sense, and the precepts inculcated by the most experienced authorities, who concur in repudiating that method as fallacious Yet these vary much in their estimates of the quantity that ought to be supplied fresh every minute, under an efficient method of governing the rates of ingress and egress.

The results range from 3 or 4 to 7 and even 10 cubic feet per minute for each person as the quantity of fresh air which ought to be introduced in addition to a supply needed for fires and the purposes of illumination.

Dr. Reid in expressing his experience says, "I am satisfied 10 cubic feet per minute for each person would be amply sufficient wherever it is possible to control the temperature, and hygrometric condition of the air to be used. The true question is to determine the amount of pure air that can be made to pass through spaces in a given time." He says also, "I am prepared to admit that a less amount will generally sustain health; but will not give the comfort nor maintain the constitution in such good condition. In extreme atmospheres, loaded with moisture or charged with special impurities or malaria, and at comparatively elevated temperatures, there is no limit to the amount of

* The date referred to was in the early part of April.

increase that proves grateful to particular constitutions. 40, 50, and even a larger number of cubic feet per minute had been given with advantage in some cases."

It might be expected perhaps that the estimates should be diminished with respect to the quantities of air for respiration, which ought to be supplied in our *school-houses*, in connexion with the foregoing considerations. To what extent ought the statements made to be modified in the case of children and youth of both sexes, who are attending schools, and therefore for the most part confined to one apartment during the greater portion of every day?

So far as a judgment can be based on the exhalation of carbonic acid alone, it would not appear that a school-room requires so large a supply of air, in proportion, as would be needed if the apartment were tenanted by adults. A boy for instance from the age of 8 to 14 or 15 does not consume more than from $\frac{1}{2}$ to $\frac{2}{3}$ the absolute quantity of oxygen absorbed by an adult. But if we consider the nature of their occupations while in school under their teachers, the comparative delicacy of the organization of the young—the need of every aid towards cheerfulness and good temper—their violent activity when out at play, often resuming their seats with their bodies covered by perspiration and their clothes saturated with moisture; then I think we shall see that we ought to be as liberal to them as towards adults. We have also to take account of their greater susceptibility to disorders, incidental to youth, and the greater facility with which infectious maladies may be communicated, unless provision exist for an abundant ventilation. It would appear that in Upper Canada this subject has engaged sufficient attention to induce the issuing recently of plans for school-houses, and for heating as well as ventilating arrangements, under the auspices of the department of public instruction. It is there suggested that a rate of not less than 178 cubic feet of space to each pupil should be reckoned necessary in the dimensions of every school-room, and that the heating and ventilating arrangements should be governed by an allowance of 200 cubic feet per hour for each pupil.

I shall allude to this again further on.

In Lower Canada, owing to various causes, amongst which may

be included the still very recent establishment of an efficient educational department, the state of the schools, in this vital particular, is less encouraging. In country parts, especially, ventilation is wholly neglected, and pupils, at certain seasons of the year, are congregated in the single-room school-houses in numbers far too great for their dimensions.* Owing to the way in which the expenses of erecting these are provided for, cheapness alone seems to be consulted. *The result is at present a most discouraging instance of unwholesome heating and deficient ventilation in the elementary schools and academies.*

It appears requisite to make a few more practical observations on this part of our subject, upon the conditions of *purity* and *temperature* already slightly noticed, the former a point of such vital consequence to our comfort and our health, and the latter forced upon our attention by the rigorous character of our climate.

With respect to *purity* it must be plain that the ventilating process must begin with furnishing fresh, wholesome air. Accordingly in the midst of a crowded population it would appear to be often no easy thing to secure that essential, owing to the state of the streets, and the immense extent of underlying cellarage, the prevalence of epidemic diseases and many other causes which present themselves in the experience of dwellers in cities.

Under such circumstances, it would appear, that the only safe procedure is, to derive the air entering from as great an elevation as possible—as through ducts, or channels, constructed to lead downwards, outside the houses into the spaces through which it is delivered into the lower parts. The reason which recommends this plan as worthy of adoption is perhaps obvious. The rising causes of vitiation in the external air, are very quickly modified by *diffusion*, and so far dissipated in the atmosphere, that there is usually, a great difference, as regards purity, between air procured at the level of the streets and cellars, and that derived from sources 30 or 40 feet high. Nor does this plan interfere with the additional precautions that may be thought requisite at times when

* It should be mentioned here that the same apartments are often occupied for hours together by assemblies of people, many of whom are adults, as in the cases of religious meetings, singing classes, municipal and other electoral proceedings.

the contiguous atmosphere is found to be unusually contaminated or too damp,—such as causing the air of ingress to pass through in contact with purifying materials, as *water impregnated with lime, preparations of lime* and chemicals, such as *muriate of zinc*, and possibly *sulphate of zinc*, which is so extensively produced now in electrical processes, without, I believe, any known corresponding outlet for its application in the arts. The entrance of *soot, dust*, &c., may be prevented by making the air in its ingress pass through gauze.

Amongst other means of local purification, I may here mention *vegetation*. Its presence has been known to prove a valuable safeguard in the worst situations. Its removal, whether on purpose or accidentally, has, in numerous instances, been found to entail loss of health upon neighbouring residents; for where the vegetable flourishes, and becomes rank, man by inhaling the principal elements of its support would lose his vigor. I need not dwell however on this point further, and shall only add, that persons, especially in what are termed *unhealthy* situations, may derive from this source, a truly serviceable adjunct to their other resources for protecting themselves from the impurity of the outer air, by cultivating appropriate vegetable productions, whether trees, shrubs, or even common garden produce and grasses, as much as possible in the immediate vicinity of their habitations.

The temperature of the air supplied in a ventilating process should be so regulated as to limit the range from about 65° to 70° Fah.—this amount being, upon the whole, that which is ordinarily most grateful to human feelings, and suitable to the wants of the system in a state of health and vigour. In this country it is quite common, owing to prevailing modes of heating, to find ourselves breathing very dry air, which has either been partially disorganized, through previous contact with heated metallic surfaces, or which, through a like cause, has been rendered the vehicle of particles of animal and vegetable substance, *scorched* and partly decomposed. It is well known that several kinds of heating apparatus, while promoting the ingress of warm air, and thus satisfying one essential condition of ventilation, are yet liable to the serious objection just stated. At the same time it is gratifying to find that attention is manifestly directed by a few towards

the subject of ventilation itself, in the introduction by patentees and inventors, of new kinds of apparatus, in the recommendations of which to the public we may observe the claim occasionally set up of having provided for that object.

I do not mean to insinuate that confidence can or ought to be entertained in the efficacy of plans advocated by persons interested in particular heating appliances. Persons are often seen to be biassed in favour of their own inventions, and in treating such a subject as this are liable to omit, unintentionally, the consideration of other essential elements not precisely connected with the mechanism or efficiency of an apparatus for furnishing caloric. We are bound to consider our own health in preference to the merits of any invention whatever, which has the production of heat merely or chiefly for its object. Every person indeed must in this behalf use his own judgment, based upon a recognition of the established laws of science, whose disinterested purpose is *truth* and the welfare of mankind.

I shall conclude these remarks by stating, that, while it is easy, in our rooms and houses, to judge of changes of temperature, by the employment of the common thermometer, we have less convenient access to instrumental means of estimating the *purity* of the air. *Lime-water* is a well-known test of the presence of *carbonic acid gas*, which it shews by becoming *turbid* on exposure to air in which that gas is contained. Dr. Reid recommends the use of what he calls a *carbonometer*. It may consist merely of a stoppled phial, containing water, with a bent glass tube attached, for holding a little lime-water in its angle, and so arranged, that the evaporation of the water, consequent on a removal of the stopple, may cause a portion of the air of an apartment to pass through the bent tube.*

2. *Simple Contrivances for Ventilation.*—We now enter upon the examination of a few arrangements and processes intended to fulfil the conditions and secure the objects of ventilation.

* Since this was written, a notice has appeared in a recent number of the London *Builder* of a new instrument, styled a *Sepometer*, portable and otherwise convenient for use, by the indications of which, it is said, the varying degrees of purity of the air, in different situations, are clearly shown, and in instances where variations of quality are utterly unappreciable by the human senses.

Now to suppose that this has been perfectly accomplished by any system yet devised, in a manner that meets *all* requirements, under *all* circumstances, would imply a degree of perfection in art, which, to say the least of it, has not been attained. Even in the open air, although the products of respiration and cutaneous exhalations, leaving us at the heat of the body, are instantly and wholly carried off, yet in several other respects (as for instance temperature and humidity) the conditions to perfect ventilation are seldom *all* present; much less then can it be expected that any single set or system of human devices can secure a perfect adaptation to all the wants created by our artificial modes of living within doors, modified, as these are, by defective architecture.

I shall proceed to take up, in the order of simplicity, some of the methods which have been adopted, or proposed, for ventilating buildings. I omit, as immaterial to our present purpose, those plans that are carried out with the aid of powerful apparatus and machinery, such as fans, wheels, blowing-machines, and so forth, employed in public edifices, and in cases where expense is unimportant,—only referring, perhaps, occasionally, to some of their minor details for illustration's sake. I also exclude such as are inapplicable in our extreme climate, although they may be remarkable for ingenuity and usefulness elsewhere.

Class 1. The simplest and most common of all methods of ventilation consists in the use of the ordinary doors and windows, which, when constantly attended to, by persons conversant with the properties and motions of gaseous bodies, and alive to the necessities of the case, may, to a certain extent, often serve the purpose of maintaining a tolerably salubrious atmosphere within. But I only name this here on account of the objections which are justly raised against what is, perhaps, merely superior to no ventilating process at all .Whatever the accuracy of fitting may be, quite a large quantity of the external air, as we have seen, will force itself in, underneath and beside doors and windows, unless the demand which may exist be met by some other special provision; also above the doors, and along the sides and tops of window-frames, air will escape,—the more rapidly when the external temperature is less than that within.

When several persons occupy an apartment of moderate dimensions, it is needless to say this escape is *wholly insufficient*, and the vitiated products speedily disperse throughout, and, by their greater elasticity, impede the draft and incoming air in such a way as to cause an almost stagnant state around. The opening of doors, and especially the upper sashes of windows, then becomes often necessary, but is liable to objection either in summer or winter. In winter, because the outer air rushes in and forces the air—the most vitiated—at the ceiling downwards, bodily, cooling it and throwing it around us so that we cannot fail to breathe again that which has already passed out from the lungs. Even in summer there are frequent occasions when dust, noise, and rain render the use of the window in this way undesirable.

Faraday, on this subject, remarks, "The builder makes the doors and windows to fit as tightly as possible, and then the poor chemist is called in to provide fresh air." Dr. Birkbeck, in giving evidence before a committee of the House of Commons, stated, "Heating and ventilation seldom enter the mind of the builder when he projects his building: he trusts to the doors and to the windows, to neither of which belong the business of ventilation. The doors admit the occupants to the chambers, the windows the light; and apertures ought to be introduced for ventilation, as regularly as the other openings." In fact it will be admitted, that the process should be independent of doors or windows, if the purpose be to supply air in the condition required, equably and conveniently. Those persons, who, on all occasions, when the weather is not too severe, throw open every aperture, in order to realise *in* a house the advantage of a more perfect process which takes place *naturally* in the open air, gain their object very imperfectly owing to architectural arrangements, while the currents of air thus set in motion are themselves frequent causes of injury to health.

It would be tedious to enlarge upon these points, and I shall only add the remark, that such methods occasion too much personal trouble, and would require a constant attention to the duty of changing the air within such as is never afforded.

2. There are several simple devices in conjunction with the use of doors and windows for providing the necessary supply and escape, avoiding also the introduction of other apertures, excepting

such as are requisite for egress of vitiated air, into chimneys or communicating flues. A crevice is cut along the upper part of the window-frame, quite through to the outside, and underneath it is placed a thin shelf of wood or tin, sloping upwards. Unless in extremely cold weather, this is found to work as well as any other of the simple plans of admitting fresh air. The outer air is thus directed upwards towards the top of the apartment, where it mingles with the more heated, and descends with the latter in part to feed the fire or stove. The opening into the flue serves to carry off into the existing draft, with the smoke, at least a considerable portion of the vitiated products of respiration and combustion.

Another method is to provide a recess in the wall of the room, immediately below the ceiling, and above the window, the whole width of the window, and about a foot deep, and to have a perforated plate of zinc of the same size fitted in; and behind the recess, an aperture leading outwards, through the wall, the size of aperture being about 9 inches square. In this case, the air entering or escaping, must pass through the perforations, which causes a certain amount of dispersion of the external air at its ingress.

Sometimes a pane is removed from the upper part of the window-sash and a tin or wooden door hinged underneath, so as to admit of being let downwards and inwards, more or less, according to circumstances.

3. Another method is the old-fashioned contrivance of placing, in one of the glass spaces, a frame containing a circular tin plate, having attached to it a wheel, mounted on an axis, with radii or vanes, bent obliquely, which, when acted on, forces the air round like the vanes of a windmill, and, dispersing it somewhat, prevents a distinct draft from being felt.

4. Another plan, sometimes seen in small houses, is to replace a pane of glass by a frame, in which a number of strips of plate-glass are arranged in the manner of a Venetian blind, and having an adjusting motion, so as to regulate the supply of air.

5 and 6. Besides these there have been used perforated panes of glass, and elongated holes in the wood-work of window-sashes, having sliding doors attached; as well as a number of other little contrivances, equally simple.

Of all such as the above, it may be said, I think, that though ineffectual, and even insignificant, when compared with other arrangements to come under our notice, the adoption of them in thousands of the smaller habitations in this country, where no ventilation is ever thought of, would be a considerable step in advance, and confer a great benefit upon the community on the score of health. It would be a mistake to assume their inutility because they are not the means of frequently changing the entire air of an apartment. The principle of diffusion of gases alone would render those simple means decidedly advantageous in all states of the atmosphere, by preventing within an apartment any excessive accumulation of an injurious kind; but, by having them constantly in operation, whether in the windows of small parlours or of the bedroom, or sick chamber, they would, in many instances, suffice for all ordinary occasions, and prove the welcome means of preventing the spread of infectious disease from centres in a way within every person's reach. In addition to means of the above-mentioned class, which may be regarded as chiefly, though not wholly, useful for admitting air from without, we must note the opportunities of escape afforded by small openings made into chimneys, or overhead through the ceiling or roof.* It must be admitted that such modes of escape afford facilities causing a greater expenditure of heat than is desirable, in our climate, during winter. The ascending heated air is commonly supposed to make for those openings in a body, so that some parts of a room, which are in its course from the source of warmth, are unduly warmed, and other parts kept at too low a temperature. I am of opinion, however, that this defect is somewhat overrated, and that it may be partially remedied by regulating the sizes of the upper openings, and by other means (not necessary to describe here) by which the heated air itself is made to disperse as it rises. When a heated gas ascends or moves otherwise through another,

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* For *egress*, in connection with the use of the ordinary stove-pipe, it has been proposed to adjust an *inverted funnel* to one of the lengths of the pipe, so that the vitiated air of an apartment, entering into the flue through the mouth of the funnel, may be constantly carried off in the draft together with the heated products of combustion from the stove.

at a lower temperature, it does not, unless the pressure or draft is great, move in a compact mass like a solid or liquid body projected in space. The motion is a rolling one: the unequally heated gases pushing out into each other in a manner which it is not easy to describe, but which can be witnessed in the convolutions of bodies of smoke in air, and in the movements of masses of steam issuing from a locomotive engine in cold weather. The same sort of movement takes place in an apartment, occasioning a greater amount of transfer of heat, *laterally*, than is generally supposed, before the heated air is finally evacuated at outlets in the ceiling. But if the expenditure of caloric were greater still than it actually is, it is surely preferable to have such outlets, which can easily be regulated in size, by means of slides adjusted to them, rather than in all circumstances to force the warm air to come down again, bringing with it the products that must, at any cost, be quickly got rid of, in view of health.

We have, therefore, in these simple arrangements, one or other of the methods of letting in and dispersing the fresh air through an upper window-pane, and the addition of a hole regulated by a slide, and communicating with the chimney, or through the ceiling overhead; a system of ventilation within every householder's reach, and one which, if it were adopted, would be a great improvement in the ways of living that actually prevail.

I must here allude to the sort of ventilation which is met with in a great many private houses, and hotels, of the simple kind now under notice. A *swinging-sash*, moving, either vertically or horizontally, is fitted above the doors—more particularly in the sleeping apartments. By these the circulation of air is promoted in the chambers, and along the passages and corridors. But, unless a further provision be made, so as to allow of escape into an upper story, and out through the roof, it is impossible to consider the system a judicious one. In hotels, especially, such apartments too often become receptacles for large volumes of unwholesome vapours ascending from the public rooms and cooking-places below; and in the night, when all windows above are closed, the best that can be said of it is, that every occupant gets his fair share of the unctuous vapours and products of respiration and combustion, and of everything else that permeates the atmosphere

of the building. In such a situation, the transient occupant of a sleeping-room is often completely at the mercy of a hurtful system; so that it becomes a question, whether it is not, on the whole, better to close the ventilator, and then, after admitting for a time the purifying external atmosphere, trust himself to the hazards of a night passed in a close room containing from 1500 to 2000 cubic feet of air pure at the outset. I may quote, in passing, the remark of Dr. Reid on the subject of deficient ventilation in hotels: "Travellers, and indeed all persons, should be charged only half-fare when they partake of refreshments in an ill-ventilated apartment; for many are the unrefreshing meals and subdued appetites that destroy the strength of the constitution in apartments loaded with the vapour of respiration and exhalation." If, however, measures be taken for maintaining in a suitable condition the air of halls and passages, the method of ventilation by means of a swinging-sash over the doors of apartments is undoubtedly one of the most convenient that can be employed. It might appear to some that the effluent air from each room would vitiate that which enters, and thus defeat the purpose; but a remarkable peculiarity of gases, when in motion through the same channel in opposite directions, presents itself in correction of the supposed injurious effect. The currents divide, each occupying a side of the conducting channel, with far less intermixture than might be expected; and, when a thin solid partition or diaphragm is placed, the separation appears to be rendered complete. This is illustrated in a familiar manner by the way in which the products of combustion are carried off from within a receiver through a tube, while, at the same time, the air necessary to support it is passed inwards; a diaphragm, in the axis of the tube, dividing the ingoing from the outgoing current, in a way that keeps the flame alive, and which, when the diaphragm is removed, is extinguished. In some such way alone can both currents of influx and efflux be sustained in many cases that might be cited; and of which a good example is furnished in the ventilation of a beehive, by the labour of their interesting occupants, whose dwelling has only one small hole underneath for maintaining communication with the external air.

As regards the whole class of processes of ventilation adverted

to, in which simple expedients in connection with windows and doors are employed, it mght be questioned whether they are not, after all, those which most merit the attention of the benevolent and ingenious, with the view of perfecting them as much as possible, and of encouraging their introduction in the habitations of that large number of persons who will not, or cannot, endure the cost of more elaborate arrangements. Under some such impulse it was, that, nine or ten years since, at a period when the Cholera was raging in London and other cities of Great Britain, Dr. Arnott succeeded in inducing the Board of Health to announce, officially, in the *London Gazette*, that, "in every ill-ventilated dwelling, considerable and immediate relief may be given by a plan, suggested by Dr. Arnott, of taking a brick out of the wall, so as to open a communication with the chimney, near the ceiling of the room. Any occasional *down-draft* will be more than compensated for by the beneficial results of this simple ventilating process." The Doctor, who appears at all times to have had the welfare of his suffering countrymen at heart,—freely communicating his experience, and his inventions also, without aiming at securing pecuniary advantage to himself,—devised a useful little self-acting contrivance, to be fitted into the chimney-hole, which he described in a published letter, dated September 22, 1849.

Had a more complete and costly process been insisted on, it is almost certain the results would have been insignificant; whereas, to use the Dr.'s own words, in the letter referred to, "The advantages of these openings and valves were soon manifest, and they are now in very extensive use. A good illustration was afforded in St. James's Parish, densely inhabited in some quarters by the families of Irish labourers, who sent an enormous number of sick to the neighbouring dispensary. I was consulted respecting the ventilation of such places. The decided effect produced at once on the feelings of the inmates, was so remarkable that there was an extensive demand for the new appliance; and, in consequence, it was soon reported in evidence before the Commission for the Health of Towns, and in other published documents, that there was an extraordinary reduction, both in the number of sick applying for relief, and in the severity of dis-

cases occurring. Wide experience elsewhere has since obtained similar results; so that most of the hospitals and poor-houses in the kingdom have now these chimney-valves; and most of the medical men and others, who have published of late on Sanitary matters, have strongly recommended them."

It should be noted that Dr. Arnott, although an inventor of many ingenious contrivances, not only preserved no secrecy respecting their principles, but is commonly esteemed to have been unbiassed by any mercenary feeling that might warp his own judgment and damage the influence of his advocacy of ventilation. On the contrary, all he says on the subject is entitled to have great weight; because it was seen, that, with disinterested feelings of humanity, he united an enlarged experience and knowledge of scientific principles.

Before finally dismissing from our view the class of most simple ventilating arrangements, it may not be out of place to remark, that their extreme simplicity or common-place character ought not to be permitted to stand in the way of recognizing their value, or of endeavours to extend the knowledge and use of them. Natural processes in general, conducive to our welfare and happiness, become, when comprehended, simple in our estimation. If art lags far behind nature, in the production of contrivances suitable to the attainment of ends sought, it is chiefly in this very feature of simplicity that the deficiency is most apparent. To reject or despise any contrivance, on account of its simple character in comparison with the magnitude of its purpose, or in the face of more elaborate devices whereby the same may be accomplished, would seem to be only a poor imitation of the Syrian leper willing to accord compliance, had the prophet enjoined "*some great thing*," but scornfully contrasting the little *Jordan* with the *Pharpar* and *Abana*, "better than all the waters of *Israel*."

* Amongst the simple arrangements noticed in this chapter, I have not expressly named that proposed by Tredgold, and, more recently, extended and patented by Dr. Chowne—the principle upon which it is understood to act in those cases in which it has been shewn to operate successfully, being to say the least of it, a somewhat doubtful assumption. A syphon, the legs of which are of unequal lengths, being placed

vertically, with the bend downwards, it has been asserted that a current will be started *downwards* through the shorter leg and *upwards* through the longer. Tredgold, however, appears to have had in view the presence of a fire, the mouth of the shorter leg being placed near to the ceiling, and the longer leg situated contiguous to and entering the chimney. Dr. Chowne proposed to carry one or more tubes, opening near the ceiling, and passing from the apartments of a house to the nearest chimney in such manner as to enter the latter at points not far above the fire places. Thus the chimney itself is made to form a part of the longer leg of the inverted syphon. In a great many cases in which the occupant of a house desires to provide for the escape of foul air from particular apartments, the plan might work successfully, even when no artificial fires are in use, because the requisite draft might be produced by the stronger action of the sun upon the exposed chimney. It has been employed to carry off the heated products of combustion from lamps, gas-lights, &c.

CHAPTER V.

ON SOME OF THE VARIOUS METHODS OF VENTILATING DWELLING-HOUSES AND SCHOOLS.

The proper time for arranging a system of ventilation for a building, intended to be occupied as a dwelling-house, occurs when the *plans for the structure are being laid down*. It is then that the important object can be provided for with the greatest certainty, and with the least expenditure, both of money and ingenuity.

1. One principal requisite is a *shaft* or vertical channel—in an extensive structure, *two or more* such shafts—situated conveniently with respect to the halls, passages, and apartments, and passing upwards through the entire height of the building, from the basement, and extending to some little elevation above the ridge of the roof. In most cases the ordinary chimney-flues may be made to answer the purpose; but the intended uses will be more completely and more satisfactorily accomplished if the shafts be merely contiguous to the chimney. In either case, the heat derivable from the ascending products of combustion may be turned to account in producing the requisite upward current in the ventilating shaft.

In the next place, the interior of the ventilating shaft is to be divided into a number of vertical channels or compartments, by means of partitions, and, while the process of construction is going on, communications provided for at suitable places, both between the shaft and the chimney, and between the shaft and the several stories and rooms of the building. Each separate room and sleeping chamber should have, if possible, a distinct channel assigned to it in the ventilating shaft.

The use of the shaft is to carry off the vitiated air, and the various noxious gases that may be generated at any time in the house. By an easy arrangement, two such shafts, having several vertical and distinct channels in each, can be provided for—one on each side of the main flue—in connection with each chimney.

The best situations for openings from rooms to be made for the purpose of drawing off, as it were, the damaged air, would, at first sight, appear to be the highest attainable near the ceiling, the inlets being suitably shaped so as to present no unnecessary obstacle to the free movement of the gases; but considerations relating to the economy of heat and its more equal distribution serve to modify that conclusion. Hence, it has been recommended to have two openings for escape,—one in the highest and the other near the lowest part of the room,—so that, in practice, when it is conceived that the effluent air is carrying off too much caloric; then, by means of suitable valves or registers, the upper outlets may be wholly or partially closed, and the lower ones made to assist in effecting the discharge. In some instances, the idea of economizing heat, prevailing over all other considerations, has led to the use of one opening only, situated near the floor.

An arrangement such as that which has been thus familiarly described suffices effectually for escape of the products of respiration and combustion in a dwelling house, so long as the heated chimney serves to warm the adjacent shafts and their compartments. Even in the summer time, when fires for warmth are not in use, it becomes available to some extent. But in any of the larger dwelling houses it is generally possible to create the requisite draft at all times by having a fire-place, whose flue enters the main chimney, put in operation in some more remote apartment, where the heat might not occasion inconvenience. In towns where gas-light is used, and in cases where the main flue, having no compartments, is employed as a ventilating shaft, a pipe with one or two burners might be laid on and disposed securely within the chimney at a convenient point; the heat from the burners could then, at any season, be made to maintain some draft, as in the foregoing instance. Even in smaller habitations advantage might generally be taken of the draft in the flue from the cooking apparatus—this being commonly in operation at all seasons of the year.

To avoid a lengthened description of details relating to the positions of the openings and the arrangement of the compartments of the ventilating shaft in connection with the several

floors, I refer to diagrams* given at the end. It may be stated, however, in brief, that the outlets for vitiated air should be placed as much as possible opposite to and distant from the places of entrance for the fresh air; so that the latter, being introduced *warmed* in the winter time, may be compelled to diffuse its caloric more widely before finally reaching the places of escape.

With respect to the supply of fresh air needed, there are, as is well known, several kinds of heating apparatus now in use, by means of which the vital fluid is warmed and passed into the apartments of a building in any required quantity. Usually the same inlets as are employed in winter may be used at other seasons and without the employment of any other means of ingress, provided only a draft in the flues is maintained for the evacuation of the air required to be withdrawn.

Some imperfections, however, and occasional difficulties cannot but be expected to attend the carrying out of this or any other system of house-ventilation in our excessive climate. But the principal circumstance that stands in the way of our attaining our purpose *perfectly*, appears to grow out of the difficulty of reconciling two opposing conditions. The one is, the deficiency of entirely self-acting means of producing a draft, *in the summer time*, to bring in fresh air and to carry off vitiated air through its intended outlets. The other consists in having too much draft, in connection with our powerful heating arrangements, to accord with economy and otherwise suit our purpose during our rigorous winters. The economical adjustment of these opposite conditions is a thing much to be desired in view of improvement in domestic architecture.

In conjunction with those modes of heating in which pipes are employed conveying warm water or in carrying steam throughout a building, it is only necessary to enclose portions of the conducting pipe within the ventilating shaft or in channels communicating with the outer air. In this way, as some contend, the most efficiently acting process of evacuation is provided for the foul air. Passing through air-chambers constructed expressly for the purpose, the quantity of warm air required for breathing pur-

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* See explanatory note at the close of this chapter.

poses is furnished in a manner similar to that which follows on the use of air-chambers with *stoves*. Hence by either method of heating, together with the ventilating-shaft, the conditions of warmth, ingress, and egress are adequately fulfilled.

2. But it is not so where only the common stove is made use of, without an air-chamber. The air to support combustion and for breathing, in that case, finds its own way in through crevices and other inlets, from all quarters, entering *cold*, and the greater portion making for the stove. Several considerable inconveniences are experienced in consequence, which it is unnecessary to detail, but which do not appear susceptible of removal, consistently with the conditions of that mode of heating. An adaptation, however, of the common stove to the purposes of bringing in the air for its own consumption and also that required for other uses, has recently been proposed,* and partially introduced. As the plan is further recommended by an accompanying arrangement for ventilation, it appears proper in this place to make such allusion to it as may afford a general idea of its nature. The method is, substantially, to attach to a stove of peculiar shape, or (as it may be styled, for the purpose of illustration) *the furnace*, in which the fuel is consumed, an outer case or covering, between which and the inner part the air is made to pass, and subsequently to flow outwards and upwards. All the air required, both for combustion in the stove and otherwise, is conducted, from without the building, in an air-tight channel, which is constructed expressly for that purpose, and terminates, inside, in an opening through the floor, over which the stove is placed and closely adjusted. The air then passing between the two metallic walls of the stove, is heated and passed in. It is essential to the arrangement that the foundations of the house and the walls of the building should be perfectly tight, so as not to admit other air besides that which is transmitted in the way described. Thus the condition of ingress of fresh air, warmed sufficiently, but not, as is asserted,† excessively heated, is complied with.

* By Mr. Ruttan, of Cobourg, C. W.

† A number of testimonials, and some descriptions, from which the facts here stated have been gathered, were published at different times by the patentee.

The accessary arrangement, whereby the warmth is retained and diffused through the building, and the process of evacuation effected, appears to be such as would satisfy all who do not object to the situation of the outlets, which, in the different apartments, are placed low down near the floors. Each outlet communicates with channels leading down to the lowest floor. The escaping air is made, in consequence of a peculiar method of constructing this floor, to pass along underneath, until it reaches a chamber or duct whence it moves into a shaft or chimney, and is eventually carried up into the atmosphere without.

As respects the applicability of this method of warming and ventilating to dwelling-houses, and indeed to buildings of any kind, it may be stated that it must be specially provided for in the outset when the structure is being built,—or at least the buildings must be expressly contrived or altered for its reception. The amount of heat *radiated* from the outer walls of the stove is stated to be, under judicious management, quite moderate.

Any improvements such as are claimed in behalf of this mode of heating, cannot fail to prove highly acceptable, especially as respects the avoidance of cold currents about the floors of rooms, and the introduction of warmed fresh air, in conjunction with the use of stoves in apartments. The foregoing system appears to be essentially a *winter* arrangement as regards ventilation.

3. There are numerous other adaptations of mere stoves in favor of which their inventors claim efficiency both in heating and ventilating.*

In a climate so cold as that of Canada in winter it is neither possible nor perhaps desirable to provide for the efficient working of ventilating processes independently of those for heating. Hence the desire of most inventors and patentees to secure for a powerful heating apparatus, the additional recommendation of being adapted to promote the ingress of fresh air into a house, to warm it sufficiently, and to admit of easy instrumentality in pro-

* A reference may here be made to the apparatus of Mr. Wilson of Upper Canada, the nature of which, together with diagrams showing the operation of a ventilating process in connection with it, and in a house warmed by his method, were published in a small pamphlet by himself. Mr. White of Montreal has brought out a very good stove, to which a complete system of ingress and egress should be applied.

moting the discharge of vitiated air. There are, however, so many ingenious inventions, and, besides, so much of conflicting opinion about their comparative merits, that it would be idle here to volunteer any statement in that behalf. But I may be permitted to say again, that, apart from the value of any particular apparatus, when viewed merely as an instrument for producing heat, none whatever ought to be esteemed serviceable for ventilation which injures, as some do, the incoming air by heating it too intensely. Some persons indeed, from an established dislike or prejudice as regards the breathing of air warmed by contact with highly-heated metal, object to the use of stoves altogether for that purpose. It would not be difficult to show that the prejudice is not, in some cases at least, groundless. At the same time, it could be made to appear in other cases that the evil has been exaggerated.

The advocates of heating by hot-water pipes and by steam are naturally amongst those who thus reject stove-heat, and, perceiving that their pipes can readily be led through portions of the ventilating flues, will be disposed to prefer their favorite apparatus for assisting in ventilation also.

There is, however, another well-known mode of heating, in which the presence of very little metal of any kind is necessary, and of none in a way that can possibly prove injurious, unless purposely rendered so. I allude to the open brick or stone fire-place. As it has, within a few years past, both in England and here, been shewn to be applicable for ventilating purposes in cases where one apartment only is concerned, I purpose mentioning its usefulness a little more particularly. The great objection commonly entertained against the use of the open fire-place proceeds from the unpleasantness of the draft of cold air rushing along the floor of the room to supply the combustion, and in part from the comparatively greater consumption of fuel. It also, as commonly constructed, heats the apartment by radiation only, and involves some extra trouble and service in supplying it with fuel. The want of economy in fuel appears to be the most valid objection in a town, seeing that the other principal defects mentioned can be almost wholly remedied. Still, there are cases in which it is, perhaps, the very best mode of heating and ventilating a single

room; as in a school-house, in a country place, where fuel is abundant and cheap. I shall, therefore, state the construction of such a fire-place, and shew how the ventilating process can be efficiently combined with its use, which will be most readily comprehended by referring to the diagrams* at the end of this section. The following are some of the advantages of this fire-place, as stated in the "School Architecture," published in Upper Canada:—1. The fire, being made against brick, imparts to the air no deleterious qualities, but gives the pleasant heat of an open fire-place. 2. None of the heat of the fuel will be lost, as the smoke-pipe may be extended far enough to communicate nearly all the heat of the smoke. 3. The current of air, heated within the hollow back, and constantly pouring into the room, will diffuse an agreeable heat throughout every part. 4. The pressure of the air of the room will be constantly outwards, little cold will enter by cracks and windows, and the fire-place will have no tendency to smoke.

The construction is not a new one, being merely a modification of the invention or improvement by the celebrated Cardinal Polignac in 1712 or 1713. Dr. Desaguiliers, a powerful advocate for ventilation, translated the work of Polignac, and caused the introduction of this kind of open fire-place in England, where it was coming into extensive use, until, through the misapprehension of its qualities, as well as misrepresentation by interested persons, it fell into neglect. Mr. Hoskins, about 15 years since, was successful in recommending its adoption in London, where, in a slightly different form, it is frequently constructed.

4. Very easily adjusted arrangements for adapting the common stove-pipe flue to the purpose of producing the required draft, so

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* In the diagrams, inlets for the air by which the combustion is sustained are not marked; and, in the absence of such, the fire is fed by the air of the apartment. I am indebted for the use of the plates, from which these and some of the other figures, viz., figs. 7, 11, and 12, have been printed, to the kindness of Mr. Hodgins of the Department of Public Instruction, Upper Canada, who has recently edited a work entitled "School Architecture"; which is, perhaps, the most valuable, in view of practical utility in connection with educational objects, that has made its appearance in Canada.

as to cause the ejection of foul air, may be effected, as shewn in the diagrams (fig. 11 and fig. 12). In these cases, a *wooden* channel or tube, having its openings leading from the apartments, is made to enclose in its higher portion a part of the smoke-pipe. It can be lined with tin wherever contiguity to the pipe might be a source of danger in the absence of that protection. In diagram 11, is shewn the mode of passing out through the roof. The other diagram (fig. 12) exhibits the arrangement in connection with a *ventilating stove*, the outer air being brought in underneath through a prepared channel, adapted to the purposes of an elementary or district school-house.*

5. *Conclusion.*—I shall now close with a few general observations suggested by the subjects of which we have been speaking. If we have taken a generally correct view of *Sanitary improvements*, it must be admitted by all that their tendency is not merely to prolong the span of life, but also to ameliorate the existing condition of society, both physically and morally.

Amongst these improvements it has been stated that ventilation is the principal. In this case I do not, of course, limit the observation to that of schools and dwelling houses. Halls of Legislature, Courts of Justice, places of worship, factories, barracks, prisons, hospitals, mines, ships, require constant ventilation; and, to a great extent, these structures are provided with it at the public expense. But, in several points of view, we may be permitted to think that our homes and school-houses present a still more important field for the exercise of that healthful cleansing process. Spending a great part of each 24 hours in our homes—our families too, living in and breathing the air they contain *constantly*,—it seems impossible to regard the object in any other light than as

* Economical modes of ventilation, such as those here referred to would, if made obligatory and generally introduced into our country schools in Lower Canada, prove of incalculable value. I may be permitted to express the hope, that, ere long, some authoritative influence may thus be brought to bear, so as to remedy evils which are wholly inconsistent with the generally prosperous condition of those whose children, as regards their health, are jeopardized. According to an estimate of the Superintendent of Education for Lower Canada there were in attendance at schools in this part of the Province in 1856, of children between the ages of 5 and 16 years, 138,240.

more important than in the case of those other public structures, which, necessary as it may be to ventilate them, are in comparison only occasionally used by the same persons. And when we consider that the life, and health, and prospects of an innocent child ought at least to be as much cared for as the health of a prisoner, or the bodily welfare of a *soldier* or *sailor*, surely our school-houses ought to be ventilated as well as our public prisons and barracks. The argument presents itself with still more force when we regard also the more tender and delicate organization of the young.

If, by attending properly to ventilation in our homes and schools, we did *not* in the end prolong the span of human existence; still it cannot be doubted but that the various evil accompaniments of this transitory scene would be largely diminished while life did last. But the fact is, one can scarcely come to any other conclusion than that one effect *would* be the extension of the average endurance of life.

Other undeniable causes enter into considerations about longevity besides such as have been here referred to. We know, for example, that intense and long-continued activity of body and mind, hardships, want of proper food and shelter, and, above all, excesses and moral depravity,—all more or less efficiently aid in shortening life. Yet, some of these very causes not unfrequently, as has been alluded to, result from extreme neglect of cleanliness and ventilation, in their effects upon the disposition and habits of thousands.

Finally, whether we concur with those naturalists who have endeavoured to make out the proper duration of an animal's life to be five or six times its period of growth, which would assign to man 100 or 120 years; whether we adopt with some most learned and pious commentators—Muis, Cocceius, Hammond—that sense of the words in the 90th Psalm, which represents Moses as speaking of those particular Jews who were then with him in the desert, and *not of the race of man generally*, or whether we take the literal meaning of his words and hold that man's ordinary limit is 70 to 80 years,—still it may fairly be questioned whether any single set of physical causes tend so much to shorten life, and to embitter it while it endures, as *bad ventilation*.

EXPLANATORY NOTE.

In the diagrams for illustration, figures 1, 2, 3, 4, and 5 are intended to shew the escape of vitiated air into and through the ventilating-shaft, as well as the relative positions of the floors, ceilings, and apertures for egress, in the case of a dwelling-house of three stories.

In fig. 1, each aperture is at the ceiling, and there is but one channel in the shaft.

In fig. 2, each aperture is at the ceiling, but the vitiated air from every story is prevented from mingling with that of the other floors, being made to pass out by itself from the ventilating-shaft, either through the wall into the outer air, or through the appropriate channel, leading into the nearest chimney.

In fig. 3, the situation of the aperture for egress is the same, but the ventilating-shaft is divided into vertical compartments, one of which is assigned to each floor.

In fig. 4, the arrangement is the same as in fig. 3, with the addition of a second aperture at the floor of each story.

Fig. 5 exhibits the same arrangement as fig. 4, the dark spots indicating the positions of the openings for escape from the several stories of the building. In this case, the *middle* compartment of the ventilating-shaft is appropriated to the *lowest* story.

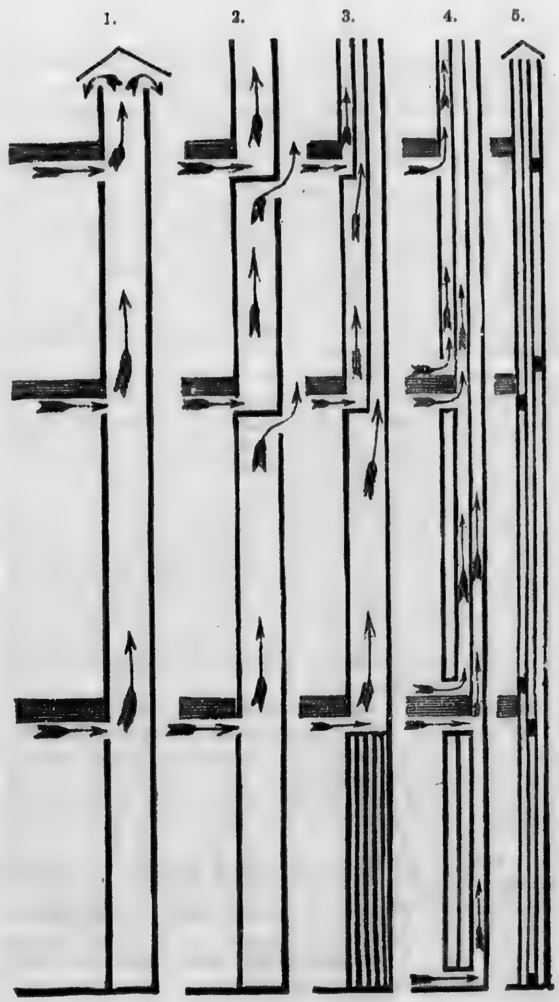
Fig. 6 illustrates a plan of ventilating a dwelling-house of two stories. A vertical section being made through the building and ventilating-shaft, the latter is seen enclosing the flue from the heating apparatus, situated underneath the lower story. The dark spots, with vertical arrows over them, shew the ingress of warmed fresh air. The other arrows indicate the circulation through the several rooms, and the subsequent mode of escape into the ventilating-shaft. In this case, the apertures for egress of vitiated products of respiration, &c. are situated near the floor of each story.

Fig. 7 is the vertical section of a building of several stories containing two class or school rooms of the whole width of the structure. The letters mark the furnace; the pipes for conveying fresh air, warmed, into the building; the furnace-flue; and the outlet from the ventilating-shaft. The packing of the foul-air flues, as well as the situations of openings for escape into the shaft, are also shown, in the side figure, fig. 8.

Figs. 9 and 11 are sufficiently described in the statements attached to them.

Figs. 11 and 12 need no further description than has been furnished in the text.

As before observed, the opening for the *ingress* of the outer air is not given in these diagrams.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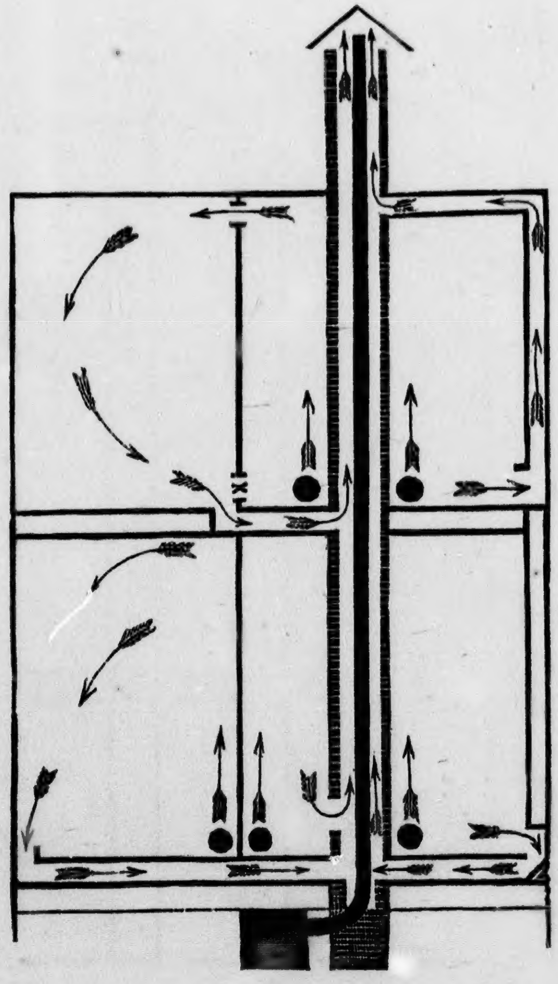

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VENTILATION

[illegible] SCHOOLS